DUAL SLOPE DUAL RANGE OSCILLATOR

RELATED APPLICATION

[0001] The present application is based on and claims benefit of United States Provisional Application No. 60/426,225, filed November 14, 2002, entitled a Dual Slope Dual Range On Chip Oscillator, to which a claim of priority is hereby made.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention relates generally to a controlled oscillator, and relates more particularly to a multiple range oscillator with selectable inputs for range selection.

2. Description of the Related Art

[0003] Oscillators, and especially on chip oscillators, are used in numerous applications involving integrated circuit products, for example. In particular, saw tooth oscillators are used in many applications and are traditionally implemented by providing a current source that charges a capacitor. The capacitor is charged and discharged to produce an oscillating output. Voltage controlled oscillators also provide an oscillator output based on a control voltage to determine the frequency of the output saw tooth waveform.

[0004] It has often been the case that a high precision current source is used to charge the capacitor to establish a precision frequency. The precision current source is typically controlled with a precision resistor. Because of the precision required, the high precision resistor is typically provided as an external resistor to an

integrated circuit that includes the current source. It would be desirable to obtain a completely integrated current source to obtain a precision oscillator output.

[0005] A VCO likewise uses a high precision resistor to obtain a precision current source to charge an appropriate capacitor. However, forming a high precision resistor on an integrated circuit is difficult and may not be workable in desired applications. That is, the use of an on chip resistor with an on chip current source typically provides very poor precision (approximately 35%) because of the variations in resistor processing in an integrated circuit. That is, the manufacturing processes used to create an on chip resistor are difficult to control to pro□uce precise and consistent results. The result is often poor precision due to process variations in the manufacturing process that can lead to inconsistencies among various integrated devices. In addition, temperature variations impact the on chip resistor and on chip current source to cause operational variations that would have to be compensated for with additional circuitry. Accordingly, it would be desirable to obtain a high precision oscillator in an integrated circuit without additional external components or circuitry for compensation.

SUMMARY OF THE INVENTION

[0006] In accordance with the present invention, a dual frequency range VCO is provided to produce a range of frequencies with a saw tooth oscillator waveform output based on an input voltage. While a number of scenarios are contemplated as within the scope of the present invention, a simple control scheme for switching between the two frequency ranges is based on a switch being on or off. By integrating the switch into the oscillator and providing it on the IC, applicable settings for both frequency ranges can be arranged on the IC. For example, a minimum operating frequency specific to the frequency range can be provided, as well as a specific frequency precision range to maintain an appropriate tolerance for

the selected frequency range. The frequency range settings are preferably consistent over changes in temperature and process variations during manufacturing of the IC.

[0007] In one range, for example, the oscillator frequency varies from 50 kHz ± 10 kHz to a minimum frequency of approximately 25 kHz ± 5 kHz. The frequency change is, for example, inversely proportional to an input control voltage ranging from zero to 5 volts. That is, zero volts on the input control voltage corresponds to 50 kHz, while 5 volts on the input control voltage corresponds to approximately 25 kHz.

[0008] Another range is provided in which the oscillator frequency can vary from 250 kHz ± 50 kHz to the minimum frequency of approximately 25 kHz ± 5 kHz. Again this frequency range is controlled with an input voltage varying from zero to 5 volts, for the maximum and minimum frequencies, respectively.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The present invention is described in greater detail below, with reference to the accompanying drawings, in which:

[0010] Figure 1 is a circuit schematic of an exemplary embodiment according to the present invention;

[0011] Figure 2 is a logic diagram of an exemplary embodiment of a control scheme in accordance with the present invention;

[0012] Figure 3 is a circuit diagram showing comparator operation according to an embodiment of the present invention;

[0013] Figure 4 is a graph showing an exemplary oscillator operation in one frequency range in accordance with the present invention;

[0014] Figure 5 is a graph showing an exemplary oscillator operation in a second frequency range in accordance with the present invention;

[0015] Figure 6 is a graph illustrating frequency versus input voltage for a first frequency range in accordance with an embodiment of the present invention; and

[0016] Figure 7 is a graph illustrating frequency versus input voltage for a second frequency range in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017] The present invention provides a dual slope dual range on chip oscillator that can be operated in a number of ranges to provide flexibility for various oscillator applications. The present invention is particularly useful in several applications, including lighting, power supplies, resonance circuits generally, or where PWM switching is used. By providing a dual slope, dual range oscillator, ranges of operations for oscillator applications can be modified in real time to provide a wider range of operation for the integrated circuit oscillator, as well as greater flexibility for oscillator applications.

[0018] Referring now to Figure 1, a schematic diagram of an embodiment according to the present invention is shown generally as circuit 10. Circuit 10 includes several representative inputs including a power VCC input 11 and a control voltage VVCO input 12. A comparator 13 receives voltage VVCO input 12 and determines when additional current is to be supplied to a capacitor CT by operation of a switch 15. Switch 15 controls the switching between the two different frequency ranges available in the oscillator output by operation of various circuitry elements to control charging and discharging of capacitor CT. A comparator 14 is provided to control the shift between charging and discharging mode of capacitor CT. The threshold of comparator 14 is shifted between 0.5 volts and 5.2 volts, for example, to obtain an oscillator output with a rapid response.

[0019] The oscillator output is a saw tooth waveform in this exemplary embodiment with a minimum frequency of approximately 25 kHz ± 5 kHz. The

minimum frequency range is highly independent of changes in temperature and manufacturing process variations. In a first range, the oscillator frequency has a range of from about 50 kHz ± 10 kHz to the minimum frequency, as the input voltage to comparator 13 changes from 0 to 5 volts. That is, when voltage VVCO input 12 is 0 volts, a maximum frequency in the selected range is produced. When voltage VVCO input 12 is 5 volts, the oscillator frequency output is the minimum value, or minimum frequency in the selected range.

[0020] A second frequency range is provided with a maximum frequency of approximately 250 kHz ± 50 kHz. The minimum frequency in this second range is again 25 kHz ± 5 kHz as in the first range for convenience and practical application. However, it should be apparent that minimum frequencies can be varied over the different ranges. As with the first range, the maximum frequency in the second range is established at 0 volts on voltage VVCO input 12, while a minimum output frequency corresponds to 5 volts on voltage VVCO input 12. Again, it should be apparent that any range correlation with input voltage can be used, as well as any number of frequency ranges.

[0021] In circuit 10, several current sources are available for charging capacitor CT. A current source I25 is derived from a current reference cell, and is always turned on to charge capacitor CT. In the exemplary embodiment, the current reference cell uses a delta VBE/R configuration to obtain a current source. Current source I25 is also used as the default current source to obtain the minimum oscillator frequency output, i.e., when no other current sources are used to charge capacitor CT. Accordingly, current source I25 is always available and always supplying current to capacitor CT in this exemplary embodiment.

[0022] Different ranges of oscillator frequency output are obtained by adding various currents to current source I25 to charge capacitor CT at a faster rate. As capacitor CT charges more quickly, the output oscillator frequency tends to increase. In one particular range, as illustrated in circuit 10, a current source I50 is coupled with current source I25 to provide additional current to capacitor CT. The point at

which current source I50 is connected to the oscillator circuit is determined by comparator 13 and voltage VVCO input 12, in conjunction with a status of switch 15. Comparator 13 compares voltage VVCO input 12 with the voltage on capacitor CT to produce an output to switch 15. Switch 15 uses the output from comparator 13 to switch an additional current source in combination with current source I25 to increase the speed at which capacitor CT charges. Which current source is combined with current source I25 is determined by other inputs to switch 15. The inputs to switch 15 could, for example, signal a specific current source to combine with current source I25 based on a circuit power up status.

[0023] When switch 15 switches in a current source with current source I25, a frequency range determination occurs. For example, when I50 is combined with I25, a first frequency range is applied, with limits of the range supplied by the range of input on voltage VVCO input 12. In operation, when voltage VVCO input 12 is approximately equal to the voltage on capacitor CT, the output of comparator 13 turns on. The output VG25 on switch 15 correspondingly operates to turn off switch MP8 to permit current source I50 to flow into capacitor CT with current source I25. Accordingly, the increased current supplied to capacitor CT provides a second charging slope that is steeper than that when the output of comparator 13 is low. That is, the charging slope for capacitor CT is shallow during charging with current source I25, and steeper during the charge supplied by current source combinations I25 and I50 when switch MP8 is turned off.

[0024] Similarly, to obtain a second range, switch 15 turns off switch MP2 to permit a current source I250 to flow into capacitor CT to further increase the steepness of the slope for charging capacitor CT. By switching the various currents into capacitor CT, charging times and thus frequency ranges can be adapted and controlled for various oscillator applications. According to this exemplary control scheme, the charging current is set at a fixed first slope for any frequency range selected when the output of comparator 13 is off, and set at a steeper slope relative to the selected frequency range when comparator 13 turns on.

[0025] Referring now to Figure 2, a logic diagram of current charging control is illustrated generally as diagram 20. Diagram 20 represents the logical components of switch 15 illustrated in circuit 10 of Figure 1. Diagram 20 shows how the digital signals VG25 and VG250 are supplied to various other components, such as MP8 and MP2, to switch between different ranges of oscillator frequency output. In addition, the outputs provided by the logic circuit in diagram 20 control the slope of the charge on capacitor CT once the output of comparator 13 turns on, i.e., input OCOMP in diagram 20 goes high. The setpoint provided by reference voltage VVCO input 12 determines the switching point for the slope change as capacitor CT charges, and the selected frequency range determines how steep the slope will be. This relationship between setpoint and selected frequency range is illustrated and described in greater detail below.

[0026] Discharging of capacitor CT is also controllable by modifying a current source IDT. Referring again to Figure 1, current source combination IDT and I25 constitute the current through which capacitor CT is discharged each period of the saw tooth oscillator frequency output. The discharge slope for the charge on capacitor CT is relatively steep with respect to the charging slopes, through the influence of the combination of IDT and I25. The discharge time for capacitor CT is chosen based on the application and should be sufficient for obtaining the maximum desired frequency in the selected range, as described in greater detail below.

[0027] The voltage range on capacitor CT in this exemplary embodiment is set to be 0.5 to 5.2 volts. It should be apparent that any type of voltage range can be chosen for the purposes of providing an appropriate oscillator frequency output for a given application. The upper and lower voltage ranges for the voltage on capacitor CT are provided by on chip voltage references that use, for example, a zener diode and a resistor divider. Any type of on chip voltage reference with reasonable accuracy is acceptable for use with the present invention. That is, expensive or complex voltage references for the range of voltage on capacitor CT need not be realized in order to achieve the present invention.

[0028] Referring for a moment to Figure 1, comparator 14 controls the shifting between charging and discharging modes of capacitor CT by varying the applied thresholds of the comparator inputs between 0.5 volts and 5.2 volts. For example, if a threshold voltage on comparator 14 is set to 5.2 volts, as the voltage on capacitor CT charges through 5.2 volts, the threshold on comparator 14 switches to 0.5 volts. This simple threshold switching scheme permits the output of comparator 14 to switch until the voltage on capacitor CT drops below 0.5 volts. Once capacitor CT has discharged through 0.5 volts, the threshold on comparator 14 is again switched to 5.2 volts to await the next charging cycle of capacitor CT. By using this arrangement, a simple and responsive oscillator switching scheme is achieved at the output of comparator 14 to provide a simple control, in several ranges, for oscillator frequency output.

[0029] Referring now to Figure 3, a circuit diagram of comparators 13 and 14 is provided generally as diagram 30. Switches MP2 and MP3 provide the comparison function for the circuit in diagram 30 to switch the output on or off. Because comparators 13, 14 may perform the same internal function while accomplishing very different tasks, the same representative control module may be used for both devices, reducing complexity of the system.

[0030] Referring now to Figure 4, a graph 40 of voltage versus time is shown for a first range of oscillator frequency output. Graph 40 illustrates operation of oscillator output over the range of frequencies for the first range, as voltage VVCO input 12 changes from 0 to 5 volts. That is, graph 40 shows higher frequencies when voltage VVCO input 12 is at a lower value than when it is at a value closer to the top of its range. It can be observed in graph 40 that the peaks of the saw tooth waveform fall closer together when voltage VVCO input 12 is a lower value, i.e., the oscillator output is higher in frequency. Similarly, the peaks of the saw tooth waveform fall farther apart as voltage VVCO input 12 approaches its maximum value.

[0031] Graph 40 illustrates the change in slope of the saw tooth waveform as different current combinations are applied to charge capacitor CT. By following the

slope of voltage VVCO input 12 plotted on graph 40, the change in slope for the oscillator saw tooth waveform can be observed for different setpoints. When the change in slope is near the bottom of the waveform, i.e., voltage VVCO input 12 is at a low value, the shallower slope provided by current source I25 has less time to influence the charging time of capacitor CT. Accordingly, the higher current combination of current source I25 plus I50 provides a higher frequency oscillator output, due to realization of a steeper charging slope in capacitor CT. As voltage VVCO input 12 reaches higher values, the slope of the lower current charge to capacitor CT has a greater influence on the charging time, and thus the frequency output of the oscillator. That is, near the top of the range for voltage VVCO input 12, nearly the entire saw tooth waveform is derived from the slope of current source I25, thereby approaching a minimum frequency value. Accordingly, the charging time for capacitor CT is related to voltage VVCO input 12, i.e., dependent upon the amount of time that current source I25 is permitted to charge capacitor CT, and the selected frequency range of operation.

[0032] Referring now to Figure 5, a graph 50 shows an overlaid relationship between voltage VVCO input 12 and the oscillator frequency output in a second range. It can be observed from graph 50 as voltage VVCO input 12 approaches zero, the oscillator output is at a very high frequency, i.e., nearly the same charge time as discharge time for capacitor CT. As voltage VVCO increases towards its maximum value, the frequency output of the oscillator is correspondingly reduced down to a minimum frequency. As with the first selected range of operation, a dual slope range of operation is shown in graph 50, where the impact of the amount of time that capacitor CT is charged with a lower current source on the frequency output is easily observed. That is, the combination of different slopes for current supplied to capacitor CT and the corresponding charging times produces the desired frequency output in the selected range.

[0033] Referring now to Figure 6, a graph 60 shows a plot of a first range of frequency versus voltage VVCO input 12. The lines on graph 60 show frequency versus voltage operation for various temperatures ranges from minus 25 to 125°C.

As can easily be seen by the plot in graph 60, there is very little variation of oscillator frequency at a given voltage set point over a large range of temperature values. Accordingly, a reliable accuracy in precision is obtained for oscillator frequency output in a variety of modes.

[0034] Referring now to Figure 7, a graph 70 shows several plots of frequency versus voltage VVCO input 12. The frequency ranges from 250 kHz to 25 kHz while voltage VVCO input 12 ranges from 0 to 5 volts, respectively. Again, as with graph 60, there is very little variation of output oscillator frequency at a given setpoint over the range of temperatures from minus 20 to 125°C.

[0035] The present invention provides a reliable dual range oscillator output based on charging times of a capacitor with a charging profile that includes two different slopes resulting from applied current. The invention obtains a variety of oscillator outputs and ranges with little variation over temperature or manufacturing processes. A particularly useful application for the present invention is in the field of fluorescent lighting. For example, it is desirable to operate an electronic ballast in a dual range of oscillator frequency values. For example, it may be desirable to have a frequency range that is very broad for starting a lamp with an electronic ballast, and then decreasing the frequency operation range for normal running mode in the lamp and ballast combination. By providing a dual range of oscillator frequency output, operational efficiency and extended component life can be realized.

[0036] Although the present invention has been described in relation to particular embodiments thereof, many other variations and modifications and other uses will become apparent to those skilled in the art. It is preferred, therefore, that the present invention be limited not by the specific disclosure herein, but only by the appended claims.